CHALLENGES OF MIGRATING TO AN ENTERPRISE CONTENT DELIVERY NETWORK

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ABSTRACT

While the benefits of e-Learning have been thoroughly documented, the method in which e-Learning is adapted to an organization is critical to achieving program goals and objectives. Until recently, the Marine Corps Distance Learning Program (MCDLP) used a decentralized architecture of remote Training and Education Points of Presence (TEPOP) servers to provide both student services and Interactive Multimedia Instruction (IMI) content to its users. Faced with increased demand for rich media, such as high bit rate video, the decision to migrate to a COTS Learning Management System (LMS), along with the desire to design and field a deployable e-Learning system, required a new architecture be developed. Designing and adapting the appropriate architecture for an organization with the unique geography, operational, and infrastructure considerations of the MCDLP imposed a significant transformation challenge.

Several other challenges faced the MCDLP team and centered around the premise that a centralized COTS LMS would allow students to manage their learning progress regardless of whether they access the system from a base, deployed, or shipboard location. While a central LMS provides obvious advantages in creating a reliable and consistent student support system, the network traffic and bandwidth loads consistent with rich media IMI greatly restrict the training experience quality you can expect from courseware delivered from one central location. Since the MCDLP can expect to see large groupings of students in very specific locations, a clear goal was to be able to locate high bandwidth IMI content as close to students as possible. To this end a feasibility study was conducted and a prototype demonstrated which resulted in the decision to deploy an Enterprise Content Delivery Network (ECDN).

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INTRODUCTION

Background

In 1997, the Marine Corps Training and Education Division and the Marine Corps Systems Command initiated a program to provide interactive web-based training and education to Marines, their family members, and government civilian employees affiliated with the Marine Corps. One of the key technical objectives of the original pilot initiative, known as MarineNet 1.0, was to increase access to e-learning products while minimizing the impact on the Marine Corps Enterprise Network (MCEN). The Marine Corps Distance Learning Program (MCDLP) designed and deployed a distributed web-based solution, which leveraged existing state-of-the-art technology while aligning with the on-going Marine Corps-wide Base Telecommunications Infrastructure (BTI) upgrade.

Early Operational Concept

The early MarineNet system was hosted on multiple Training and Education Point of Presence (TEPOP) application servers which provided a web-based student interface, content hosting, and management tools to monitor student progress, training statistics, and network utilization. The servers were installed at Marine Corps bases that had high concentrations of prospective distance learning students. The servers were designed as regional content repositories and provided on-line interactive content for the on-base student population. The servers also provided an interface to the Marine Corps Institute Automated Information System (MCIAIS). MCIAIS is the Marine Corps database of record for students who enroll in formal distance learning certification courses.

The distributed architecture was driven by the requirements to:

- Leverage the MCEN infrastructure
- Operate within DoD mobile code policies while providing engaging content; and
- Mitigate the effects of limited inter-base data communication capacities.

These constraints drove a full TEPOP server installation at every military facility whose student population required access to media-rich instructional content. In addition to the server infrastructure, the MCDLP fielded networked Learning Resource Centers (LRCs) to increase access to content and research materials for Marines without the benefit of personal computers or access to government-owned workstations. Finally, the program integrated Automated Electronic Classroom (AEC) facilities into the distance learning network at the largest Marine Corps bases and formal school locations in order to facilitate hybrid resident and distance learning curricula.

Dedicated on-site technical support staffs maintained each TEPOP server suite and were responsible for operation and maintenance of the LRC and AEC facilities. As new distance learning courseware was released, the content and media were distributed to the support staff on CD-ROM for subsequent hosting in the TEPOP content repositories.

Minor upgrades to the MarineNet software improved the performance and the user interface, and while the technology infrastructure met many of the Marine Corps' unique distance learning requirements, it still exhibited significant operational and technical limitations.

Limitations of the Distributed Architecture

As early TEPOP installations were completed and system utilization increased, operational and scalability challenges quickly became apparent. The early custom-built learning management application, circa late-1998, was extremely limited in its capability to provide detailed student progress tracking, reporting, or on-line testing. The web-based application was intended only as a short duration "proof of concept" that could provide limited e-learning services until standards had stabilized and a commercial-off-the-shelf (COTS) product could be integrated. However, the software proved reliable and met the basic needs of the students as a content launch platform and was therefore retained with minor upgrades even if it was somewhat limited in terms of features.

Courseware integration with the learning management application was problematic from the outset due to a lack of industry standards, changing technologies, and the sheer number of different content providers. It seemed as though every course rollout was unique even though the MCDLP program management office took special care to specify and document interface requirements.

The original distributed database architecture also presented significant complexity for maintaining the consistency of student enrollment data for a highly mobile student population. As the number of TEPOP installations increased across the enterprise, the intercommunication and synchronization issues between the TEPOP servers escalated. In addition, robust e-learning support for Reserve Marine units was impossible with the state of technology and infrastructure during this early prototyping period.

Configuration management of the distributed architecture to include hardware, software, networking systems, and courseware continued to grow in complexity and cost. Compounding the situation was the cost of deploying and manning new TEPOP server suites at an increasing number of locations as distance learning awareness and popularity increased.

Moreover, new requirements were emerging to provide forward deployed Marines with access to full featured distance learning resources comparable to the state-side learning environment in order to maintain their warfighting and technical skills, meet professional development requirements, and compete for promotion while on extended deployments.

This decentralized and site-specific architecture constrained rapid horizontal expansion of the distance learning capability to other areas that were becoming mission critical to the Marine Corps.

Refining the Vision

As program goals and technology evolved, and in anticipation of the transition to the Navy-Marine Corps Intranet (NMCI), previous architectural decisions were re-examined to improve system performance and reduce cost.

The re-engineering effort had three major design goals:

Goal #1. Deploy a centralized COTS Learning Management System (LMS) capable of interfacing with a large number of deployable components

Goal #2. Deliver high quality, media-rich, and interactive web-based content to an even larger student population

Goal #3. Implement an enterprise content management, content distribution, and content delivery solution in order to control configuration and distribution costs

The outcome of the re-engineering effort resulted in a new MarineNet architecture. A high-level system view of the new MarineNet distance learning target architecture is depicted below (see Figure 1). The system features a centralized LMS and content repository, distributed content delivery engines, and a deployable distance learning solution all interconnected using the MCEN.

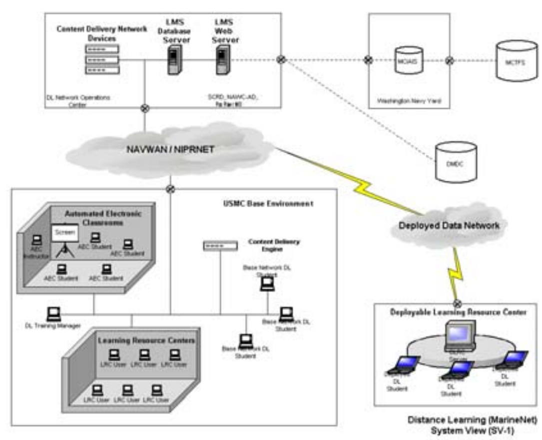

Figure 1. MarineNet System View.

MarineNet distance learning products are hosted on content delivery engines located aboard each base, station, or military installation where a distance-learning requirement exists. Today distance learning content is hosted at every major Marine Corps installation. Access to the locally hosted content is controlled through the LMS application located at Distance Learning Network Operations Center. The LMS application communicates with the Marine Corps Institute Automated Information System (MCIAIS), located at the Washington Navy Yard, to pass student tracking and completion information. MCIAIS ultimately passes student training information to the Marine Corps Total Force System (MCTFS) for incorporation into the student master personnel file. The Deployable Learning Resource Center (DLRC) system performs a similar function, however, LMS operations and content are stored in the local DLRC database. Only selected student management data is passed from the DLRC to the master LMS.

This paper describes the design and implementation challenges encountered in achieving the three stated program goals and in the transition efforts to the new MarineNet architecture.

GOAL #1. DEPLOY A CENTRALIZED COTS LEARNING MANAGEMENT SYSTEM (LMS) CAPABLE OF INTERFACING WITH A LARGE NUMBER OF DEPLOYABLE COMPONENTS

LMS Selection

The Marine Corps Distance Learning Center staff conducted an extensive survey of the commercial LMS marketplace and carefully studied e-learning standards while refining their LMS requirements. Nine commercial LMS products were evaluated during late 2000 and early 2001 in various laboratory environments that were configured to simulate actual operational scenarios before a replacement for the MarineNet 2.0 system was selected.

Basic learning management services such as user authentication, student registration, content delivery, course management, on-line assessment, role-based security, and reporting are not unique to the Marine Corps distance learning environment and several of the commercial solutions were able to meet these functional requirements with minimum additional configuration. However, the specific system requirements to interoperate with legacy information systems, widely dispersed content delivery systems, and deployable learning systems operating intermittently in a "reach-back" mode quickly reduced the field. During the selection process, the Marine Corps also considered LMS solutions that were already certified as AICC AGR-010 compliant and could be extended to SCORM conformance in the near future as a selection criteria.

The Joint-ADL Colab, who had completed a similar evaluation for the Navy earlier in 2001, validated the Marine Corps' independent assessment results of the various LMS products and the Navy and Marine Corps soon collaborated to begin implementing ThinQ Learning Solutions in their respective e-learning environments.

LMS Capabilities[i]

The Marine Corps' version of the ThinQ LMS is used to manage a student's access to distance learning content and services and to maintain student on-line learning progress and history. The MarineNet LMS has the following capabilities:

- Eligible students may create accounts
- Students may view the distance learning course catalog
- Students may enroll in web-based, paper-based, and CD-ROM courses
- Students may enroll in any distance learning curriculum (on-line or traditional) based on certain prerequisites
- Students may launch on-line courses
- Students may review their course progress
- Students may review their distance learning transcript history
- Students may take on-line assessments and receive immediate feedback and credit
- Students may print completion certificates
- Generate pre-formatted and customized reports based on system roles and privileges

When a registered student logs into MarineNet they are provided with a view of all the courses offered via distance learning regardless of the media. Prospective students may request enrollment in any distance learning course. Enrollments in distance learning courses are then managed through access levels and course prerequisites. In the MarineNet LMS, students are assigned an access level that governs their ability to enroll in certain distance learning certification courses. Active duty and Reserve Marines are the predominant student population and they are granted access to all courses in the LMS course catalog. Government civilians, military personnel from other services, contractors, and family members are granted lower access levels restricting their enrollment to certain content. In addition, students currently accessing the LMS from remote locations are restricted from enrolling in paper-based or CD-ROM courses.

The MarineNet LMS also takes into account the mobility of Marines and provides the ability for users to interact with the MarineNet system regardless of their location. However, the current MarineNet architecture is an intranet-only solution and content is not available to the students via the Internet at the time of this writing. The MarineNet architecture will accommodate an Internet content delivery solution later in calendar year 2002.

LMS Configurations

The engineering team for the USMC Distance Learning Center designed the software system architecture to overcome many of the previously identified operational and technical issues. A centralized Master LMS configuration was selected to increase system scalability, performance, and data consistency. In addition, the Master LMS configuration significantly reduced the number of system interfaces that had to be managed. Interfaces were now limited to MCIAIS, Dependents Enrollment Eligibility Reporting System (DEERS), and a few deployed systems rather than the previously fielded TEPOP server suites and the external systems which numbered over twenty. Another significant benefit of the centralized LMS architecture was a reduction in the number of firewall connections to be maintained. LMS technical expertise could also be centrally located and server operation and maintenance costs significantly reduced.

For the deployable solution, the commercial LMS had to be customized to operate in a stand-alone configuration providing an autonomous capability for deployed Marine units. This “store and forward” configuration is controlled by the DLRC administrator on the distant end who initiates synchronization scripts to transfer student enrollment and performance data to the Master LMS when a communication channel is available from either the shipboard or forward deployed tactical environments.

LMS Implementation Lessons Learned

The LMS implementation team learned many valuable lessons during system selection, customization, prototyping, and final configuration.

While product demonstrations and *Plugfests* proved beneficial, hands-on operation of the various LMS products in a representative environment was invaluable during the selection process. Commercial systems vary widely in capabilities and feature sets and live testing is crucial to identifying potential gaps and implementation problems with these products.

Our market surveys indicated that nine to twelve months is required on average for organizations to implement an enterprise LMS solution. In spite of aggressive timeline goals, our LMS implementation team required thirteen months to fully integrate the Marine Corps LMS solution. Integration with legacy information systems was the major cost and schedule driver even when external interfaces were clearly defined before the project was initiated.

Content integration with the LMS itself was relatively easy as most content vendors were familiar with emerging e-learning standards and commercial LMS implementations of the various specifications. However, interfacing the LMS with distributed content delivery engines in order to overcome mobile code and firewall constraints added enormous technical complexity to the Marine Corps LMS implementation.

Standards and specifications are valuable management tools if both the LMS and content vendors closely follow them. Extensive testing was required to validate standards conformance and interoperability between content and the LMS for every course deployed or new LMS feature incorporated.

Extensive customization of the LMS application software and database was required to extend the capability of the commercial LMS to operate in the deployable environment. The Marine Corps found that almost every commercial product reviewed required a similar level of customization effort to meet this unique requirement and the expertise of the vendor’s integration team became a key selection criteria. This part of the customization effort became critical, as was a requirement for meeting the certification criteria for shipboard operation.

GOAL #2. DELIVER HIGH QUALITY, MEDIA-RICH, AND INTERACTIVE WEB-BASED CONTENT TO AN EVEN LARGER STUDENT POPULATION

Integrating Legacy Content with the New Environment

Conversion of legacy content is a major issue for any organization transitioning to a new LMS much less a new distribution and delivery infrastructure. At the time that the Marine Corps began the LMS integration effort, the SCORM specification was still in its infancy and the MCDLP decided to proceed with the more mature HTTP AICC Communication Protocol (HACP) specification as an interim solution for the content to LMS interface.

The Marine Corps had an advantage over most large organizations in that it did not have a significant number of legacy courses to convert as part of the transition. However, it did maintain a large library of commercially procured courses that required re-configuration to operate within the new architecture. The transition to a significantly different architecture presented the program office with an opportunity to make subtle changes to the software design specification to improve security and configuration management, but also imposed new constraints for Marine Corps content developers.

Software Baseline and Plug-in Issues

The MCDLP had always maintained excellent configuration management control over its infrastructure; however, control over other managed environments across the Service continued to be a problem. Specifically, while most software versions are clearly specified for the enterprise, configuration management of media players and other so-called software plug-ins are not well defined. Version control of media players is essential for the proper operation of media-rich content and as a result some workstations today still have problems using the media if they are not properly configured.

The transition to the new distributed content environment enabled the program to reduce the number of software plug-ins used in the various legacy courses and eased the distribution of approved plug-ins by being able to quickly distribute and locally host the software on the content delivery engines for subsequent download as you might any other type of content.

Multi-domain Issues and Cookies

The Marine Corps operates a multi-domain environment, as do many large and geographically dispersed organizations. Additionally, local administrators manage the workstations within their local commands, and while similar configurations exist, they are not exactly the same across the enterprise which often proves to be an issue for interoperability with various multi-media technologies. One example is local security policies regarding the use of cookies. Many Marine Corps administrators had turned off cookies as part of their “locked down” workstation configuration, therefore some of the commercial content that used this technology could not provide student progress tracking in the new MarineNet environment. The LMS integration team had learned that the cookie specification was not intended for use in a multi-domain environment. Therefore, in the new MarineNet environment, progress information was lost after the student session ended and no data was returned to the LMS. After extensive testing of different implementations, it was determined that content that stringently conformed to the AICC specification worked the most reliably in the new environment. This lesson learned influenced the MCDLP to change commercial content providers in one instance in order to provide fully functioning content to the students. This situation was not apparent during the early architecture implementation when the LMS and content servers were collocated within the same Internet domain.

Directory Structure and Paths

Distributing content to remote servers can be challenging, particularly if they are unattended devices as envisioned for the new MarineNet environment. Automatic distribution of content creates certain unique challenges especially for referencing media locations within web-based content and configuring the system to update files remotely as they are changed. One way that the LMS implementation team overcame these challenges was to standardize the directory structure for all distributed content servers. The module, lesson, topic, and media files are always located at the same directory hierarchy level thus reducing content errors due to missing or outdated files associated with a specific piece of content (see Figure 2).

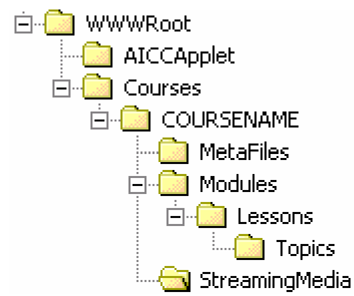

Figure 2. Sample Directory Structure.

Additionally, the file update performance for content is improved as only new or modified files are distributed across the wide area network rather than entire directories of content.

Another approach to reduce hyperlinking reference errors for media was the use of relative path addressing versus absolute addressing within the content so that files could be used in a distributed environment without requiring additional modification on the distant end.

Custom API for Runtime Communication

The MCDLP also developed a custom Application Program Interface (API) similar to the SCORM API to maintain LMS session and AICC tracking information in the distributed environment. The API and all supporting documentation have been provided to the Marine Corps content developers as part of the newly revised MarineNet 3.0 Courseware Interface Specification.

Support for Streaming Media and Embedded Media Files

The new architecture also supports both embedded and streamed media and is a tremendous capability for delivering video while conserving limited bandwidth on campus and local area networks. However, each base operates a slightly different security architecture and the use of proxy servers that strip out ActiveX code make the use of media players difficult in some base environments. This problem is still unresolved but is being addressed with Marine Corps Information Assurance staff.

GOAL #3. IMPLEMENT AN ENTERPRISE CONTENT MANAGEMENT, CONTENT DISTRIBUTION, AND CONTENT DELIVERY SOLUTION IN ORDER TO CONTROL CONFIGURATION AND DISTRIBUTION COSTS

Architectural Changes

The original TEPOP-based architecture provided a distributed web-based application and courseware delivery solution that relied on database communications to share student information with a central MCIAIS database at the Washington Navy Yard. While this architecture was implemented and operationally sound, it became apparent that the cost of deploying and manning a large scale distributed TEPOP architecture would become prohibitively expensive.

The decision was made to replace the TEPOP-based architecture with the centralized LMS. The LMS would be hosted at the USMC Distance Learning Network Operations Center located in Patuxent River, Maryland and would provide a single access point for the distance learning community to all MarineNet resources. The low bandwidth web browser transaction activity associated with LMS access can be easily supported from a single site with little impact on the wide area network infrastructure even considering the size of the target user population. This decision eliminated the necessity, along with the cost, of deploying and manning TEPOP server suites to support the original distributed architecture.

Architectural and Technical Challenges

But what happens to the content in a centralized LMS architecture? Moving to a centralized courseware delivery model is one solution, but once the student transitions from accessing LMS services to launching and interacting with interactive multimedia courseware the considerations change significantly. First, the bandwidth required to deliver interactive, streaming courseware over a wide area network to large numbers of users simultaneously would increase dramatically and consume network resources. Second, security policy makes the use of certain types of technologies impossible through security boundaries. Therefore, it became apparent that for MarineNet to operate successfully utilizing a central LMS, a new courseware delivery strategy was necessary.

The original TEPOP-based architecture provided for a distributed content model that was operating successfully. But along with this model was the requirement to staff each site to receive, load and link courseware to the local TEPOP LMS course catalog. The dilemma then became how would we move to a centralized LMS model, retain our distributed content model with linkage to the LMS, and at the same time minimize our manpower requirements. Our goal remained to locate content as close to the user as possible to reduce network hops, jitter and latency associated with access along a single, central communications link. To do that our architecture would have to provide for content delivery devices capable of supporting HTML and streaming content, allow courseware and other media to be transferred to the devices from a central location, rehosted as close to the users as possible, and provide for web redirection from the central LMS site.

In addition, there was the major technical requirement for the architecture to overlay onto the Marine Corps Enterprise Network (MCEN) operated and maintained by the Marine Corps Information Technology and Network Operations Center (MITNOC). This required the new system to interoperate and comply with all operational and security requirements of the MCEN network and at the same time minimize the impact on the enterprise wide area network bandwidth. This severely limited the TCP ports available to conduct the communications necessary to manage the system and became a critical factor in our final design decisions.

System Description

Our approach to the architectural and technical challenges was to develop and deploy a private Enterprise Content Delivery Network (ECDN) capable of providing the four key elements our architecture demanded:

- Edge-based content media engines which can store and deliver rich media files
- Content distribution and management which pre-positions content to media engines and manages the health of the network

- Content redirection which redirects user URL requests to the closest available media engine
- Overlay onto the MCEN and meet all MITNOC security requirements

In addition to the four key elements outlined above, other benefits were realized as well:

- Scheduled distribution of courseware during off hours to minimize network impacts
- Ability to provide interactive courseware to sites not previously considered due to bandwidth or cost constraints

The key components of the ECDN consist of InfoLibria's Content Commander (CC), Director, and Content Delivery Engine (CDE). The Content Commander, located in the DL NOC, is responsible for managing the distribution of the courseware in the ECDN. It is directly connected to the content server that serves as the repository for all MarineNet courseware. The Content Commander pre-positions courseware to the base CDEs and monitors the communication and health of the CDEs. The CDEs, positioned at selected Marine Corps bases and installations, receive, store, and deliver the courseware to user desktops. The Director intercepts courseware launch requests and rebuilds the URL allowing the request to be redirected to the nearest CDE.

System Operation

The operation of the ECDN can be broken down into four major processes:

- Content distribution
- User access to the LMS and content
- Redirection of users to content
- Courseware delivery

Content Distribution

MarineNet courseware is hosted in the master content repository located in the DL NOC. Based on a scheduled event process, content changes are published as jobs from the Content Commander to the remote CDEs over TCP Port 443. Job status and completion information passes from the remote CDE back to the Content Commander over TCP Port 80 (see Figure 3). The content distribution process is scheduled using the Content Commander web interface. Jobs are scheduled to minimize network impacts.

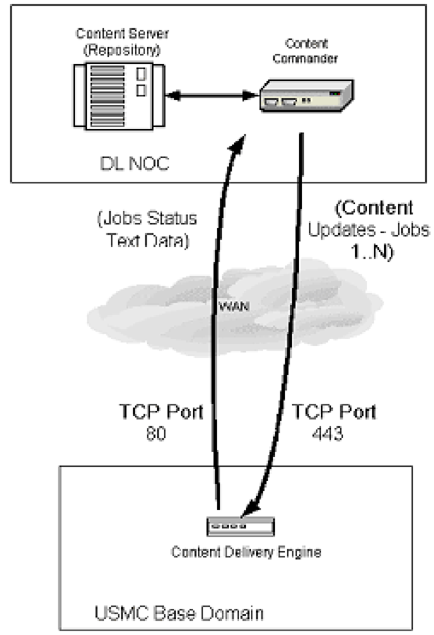

Figure 3. Content Distribution.

User Access to the LMS and Content

The student uses their web browser to access the MarineNet LMS. Once the student's identity is validated by the LMS, the student can select courseware via the course catalog. The LMS generates and returns student session information and the student initiates a course launch request (see Figure 4).

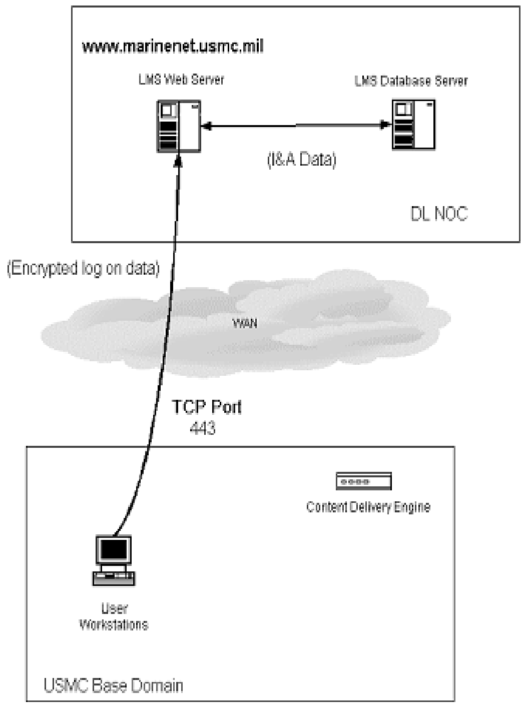

Figure 4. User Access to LMS and Content.

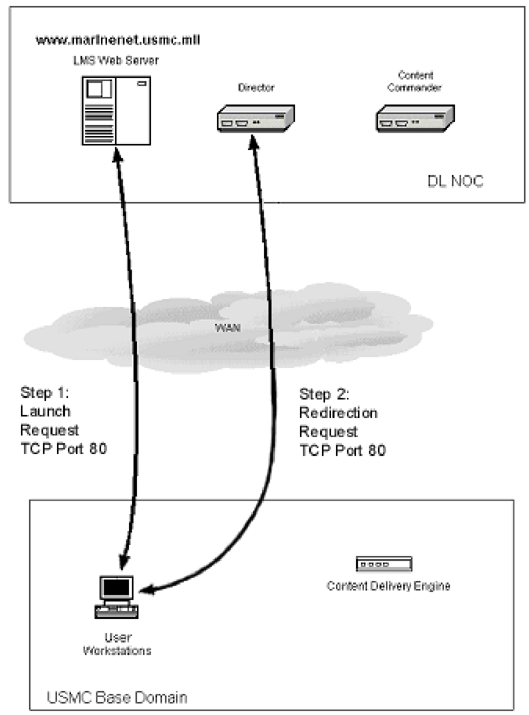

Figure 5. Redirection Process.

Redirection Process

Student session information and the courseware launch request pass from the user's browser to the Director via TCP Port 80 (see Figure 5). The Director determines the source network that the request originated from, selects the closest CDE, and returns to the user's browser the appropriate courseware URL request for the local CDE.

Courseware Delivery

Once the initial courseware launch request is redirected to the local base CDE, courseware delivery is provided via the base network infrastructure over TCP Port 80 (see Figure 6). This provides for higher bandwidth courseware to be delivered via the high-speed local base backbone.

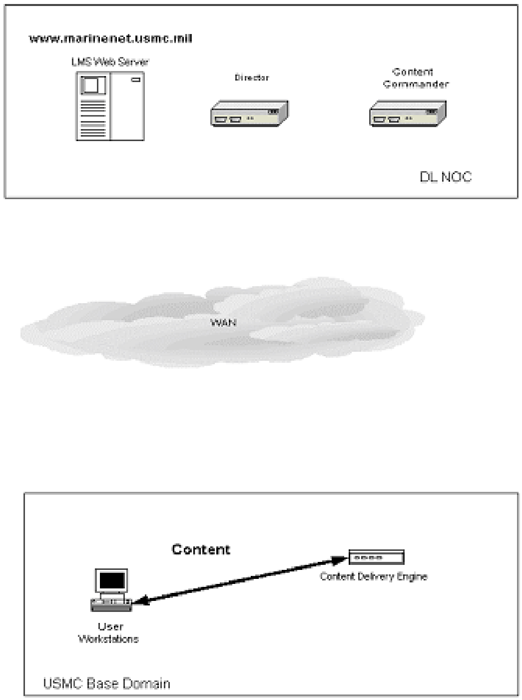

Figure 6. Courseware Delivery Process.

Security Considerations

As part of our architecture decisions, we were faced with answering two basic security questions: What level of security is required to protect the ***distribution*** of the courseware during the transfer from the Content Commander to the CDEs? Once hosted, what protection is required during ***delivery*** of the content from the local base CDE to the user desktop?

Cross enclave communications between the Content Commander and the CDEs presented the greatest challenge during implementation. The USMC security policy mandated that all ECDN communications initiated from outside the local base had to first be approved by the MITNOC. Communication had to occur over TCP Port 443 and meet FIPS 140-1 standards for encryption. To meet this requirement the Content Commander contacts each base CDE via HTTPS. All CDEs are SSL-enabled to allow communication over HTTPS. Once secure communications are established, the CDE requests a content push from the Content Commander. The CDE sends job status information to the Content Commander via HTTP. Content delivery from the base CDE to the end user workstation is accomplished entirely over HTTP.

The decision not to encrypt the delivery of content was made for two key reasons. First, the MITNOC security policy and procedures provided an extremely secure environment for the ECDN and in particular the base CDEs. Secondly, the performance issues related to the encryption and de-encryption of interactive streaming courseware made HTTPS an unattractive alternative.

CONCLUSION

While the original MarineNet architecture met many of the initial program goals, the MCDLP soon realized that to effectively deliver high quality e-learning to a rapidly growing student population, and improve system performance while reducing life cycle costs, required a new architecture.

This paper described the complexities and key design considerations associated with the migration from the early distributed, web-based e-learning architecture to the current centralized LMS with a deployable component, media rich content, and an enterprise content management solution. Even with the extensive experience the program gained developing and testing a limited prototype, this project highlighted the fact that the considerations to successfully implement an enterprise distance learning system are numerous and wide-ranging.

As discussed, several critical components exist in an enterprise-wide solution, from defining LMS operational and technical requirements, transitioning legacy courseware to the new environment, to designing and integrating the content delivery network. However, the most important factor to the successful deployment of this enterprise distance learning solution was the committed and integrated management and engineering team supporting the program.

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[i] MarineNet Learning Management System Capabilities Overview by Jeffrey Engelbrecht and Sara Foley. June 21, 2002.